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PROGRAM ON APPLICATION OF COMMUNICATIONS SATELLITES
TO EDUCATIONAL DEVELOPMENT

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FUTURE DEVELOPMENT OF INSTRUCTIONAL TELEVISION

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1. Summary and Conclusions

1. Television instruction could be a magnificent innovation of great importance. It holds large promise in lectures, display and demonstration; in computer assisted instruction; in home as well as school education; and in education of both adults and children. The prospects include increased individualized instruction; repetitions for slow learners, acceleration for fast; and offerings from the best of teachers to all students. Cost savings are also possible.

2. In this paper, we focus on ITV in schools. This is now in an undeveloped state for two reasons. Technology, both hardware and software, is still immature and has been expensive. And teachers have yet to learn how to use the innovation. The first important stage in the development of ITV is for teachers to experiment with and use TV programs and to learn how to incorporate them in classrooms.

3. A breakthrough is now at hand for this stage, which will both greatly reduce cost and assist teachers in their learning how to use instructional TV. This is the perfection of inexpensive video tape recorders/players (VTR) and inexpensive tapes and cameras. If schools were provided with these, teachers could view and re-view tapes. They could consider, learn, and experiment with ITV over the next several years, each at his own speed and in his own subject matter. We have conceived a "package A", which consists of 10 mobile VTR's and TV sets, a tape library, and several TV cameras per school of 50 rooms, and proportionate equipment for schools of other sizes. This would cost only about $5 per student per year, less than 1 percent of the usual school budget. It would seem a small price to pay for successfully introducing and planting ITV in the educational establishment.

4. We next consider the subsequent use of TV in schools as a major instrument in instruction. We conceive of ITV employed in up to 20 percent of class time in some school districts beginning in about 1974, and conceive that the innovation spreads rapidly to other districts. If an active head-end at each school transmits the ITV programs by cable to the classroom it would cost about $33 per student per year. If the city school district transmits the programs to the classrooms it would cost only about half as much; this is due to economies of scale in the head-end facilities and labor.

5. It appears that the most promising system for school ITV in this latter developed stage is a dedicated school-district cable system, which we have termed Package F. This is a 40 channel cable to each school and thence to each classroom. On its multiple channels, the school-district head-end transmits a schedule with numerous repetitions of each program to accommodate diverse individual classes, and also transmits programs in response to special request from teachers. In addition, this system includes a limited number of VTR's, TV booths, cameras, etc. in each school for individual teacher and student use. This aggregate of 40 channel cable services and other facilities costs perhaps $15 per student per year, about 2 percent of the average school budget. In turn, it provides TV instruction for an average of about 20 percent of class time. The innovation offers considerable opportunity for improving the quality and content of the schools' instructional offerings, or for reducing cost, or both.

6. The FCC sponsored 4-channel ITFS service (or 4 leased channels on a commercial CATV system) appear less desirable. Relative to the 40 channel cable service, above, they provide less flexibility; would be slightly more costly for approximately equal service to classrooms; and in the case of ITFS it is less favorable in signal quality and less attractive for potential expansion of ITV to home instruction.

7. Satellites distributing national programs have been proposed as a major system in ITV. One concept conceives of service from a national head-end facility via satellites to reception equipment at individual schools; this would substitute for active school head-end facilities. Another concept conceives of service to a city school-district cable system from a national head-end facility and satellites to individual city reception equipment; this would substitute for active city head-end facilities. In our lack of knowledge of the cost of satellites and satellite reception equipment, we are unable to estimate reliable cost comparisons. We do roughly estimate, however, the national cost of the alternative non-satellite system. This is the cost which the satellite system, if it were of equal capability, would have to equal or improve upon in order to be economically advantageous. We are now engaged in economic research on such satellite systems.

8. Satellites have also been proposed for areas with small and dispersed populations, such as Alaska. With the advent of inexpensive VTR's and tapes, this attractive innovation is becoming available for such areas. The nature of the costs of a school or classroom VTR system is that they are approximately proportionate to population numbers. Thus, small populations can be served at small costs. In Alaska, for example, the individual classroom or individual school VTR system could provide ITV to its 78,000 school students for a total of about $3 millions per year, including TV sets. This is alternative to a specialized, many-channel Alaska satellite which would broadcast to school head-end receivers, with distribution on a school wire system to individual TV sets. The $3 millions is thus a rough estimate of the cost which the Alaska ITV component of a satellite system, if it were of equal capability to the VTR system, would have to equal or improve upon in order to be economically advantageous.

2. Introduction and Design

We have speculated on the possible stages and sequence of development of television in grade and high school education in the next half dozen years or so.* Very early we discovered a seeming paradox. Television has been around for a generation or so. It is widely appreciated to be a medium of large potential for improved quality and efficiency of school instruction. The Sesame programs have been greatly applauded. A number of areas--Hagerstown, Md.; Dade County, Florida; the States of South Carolina, Kentucky and New York; and others--are seriously embarked upon ambitious television instruction programs.

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*Our study began as an inquiry into the possible use of satellites for television instruction in schools. But it then became apparent that, except for unusual situations, such use of satellites would depend in the first instance upon the adoption of television instruction in schools. Satellites are potentially a very efficient mechanism for delivering television programs to schools. They offer nationwide distribution of signals from a single broadcast point, which could permit large economies of scale in transmission facilities, tape libraries, personnel, etc. The uses and effects of satellites will, however, be constrained by the extent of use of television instruction. In turn, adoption and enlargement of television instruction will depend upon attitudes of school teachers, their capabilities and training, costs and finances, and other characteristics of the U.S. educational environment.

It is expected that the Center's project will focus on satellites in other papers; here we give only preliminary comments on satellites. In other papers, also, we would consider educational uses of television beyond in-school instruction of elementary and high school students. There also we would consider carefully special areas such as mountain sections and Alaska. Here in this paper we are primarily concerned with the more usual U.S. cities.

For major compilations of background information and long bibliographies, see two major papers from the Center for Development Technology: J.P. Singh and R.P. Morgan, Educational Electronic Information Dissemination and Broadcast Services: History, Current Infrastructure, and Public Broadcasting Requirements, Washington University, August 1971; and J.R. DuMolin, Instructional Television Utilization in the United States, Washington University, October 1971.

The Midwest Program for Airborne Television Instruction (MPATI) is generally acknowledged as having been significantly productive. In some foreign countries--Japan, the United Kingdom, Belgium, Netherlands, others--television is an important component of the national school instructional program. And, yet, in the United States generally, television is now playing a trivial role in school instruction. In the Nation as a whole it probably occupies only a few of the 1,000 or so school instructional hours with which each of our children are provided each year. The Nation spends an average of about $800 per child for its school population of more than 50 million pupils. But not more than several dollars of the annual outlay per child is for television or sound film instruction. In St. Louis last year, for example, the City school system allocated only $100,000 of its total budget to the local ETV station for television programs for schools, and only a miniscule portion of its budget for television receivers and maintenance. A survey revealed tiny use of the programs due to schedule difficulties, program quality, lack of previews, and inadequacy in numbers of sets. The City has now eliminated most of its support payment.

Thus the seeming paradox: an alleged great innovation for school instruction which, however, school personnel do not use.

The explanation has two main strands. First, our Nation has not a school system, but more than 20,000 systems, each of them in significant degree an independent decision-making unit. And, beyond this, the individual teachers and faculties have considerable decision-making power as regards instruction in their individual classrooms. Introduction of television instruction depends upon the decisions of these education

establishments and individuals. The decisions, that is, depend upon the teachers individually and in each school: their knowledge of the innovation; their opinions of television instruction in its various aspects; their views on how it can or cannot be woven into their instructional schemes; the schedules of their classes and of the program broadcasts; their concerns and fears for job performance, security, and rewards; their prior training; etc. The decisions also depend upon the educational organizations--the professional associations, the unions, and the state, local and Federal governmental bureaucracies.

Second, the innovation is a very new and immature one, despite the fact that the television phenomenon was introduced more than a generation ago. Some of the instructional television programs may be very good, but some are horrible. Program libraries are small. Teacher access to previews, necessary in order to meld the TV program into the overall instruction effort, is so poor as to insult. Some of the hardware has been developed and is available, but some is non-existent or subject to frequent breakdown. Compatibility problems are numerous in tapes, players, wavelengths, etc. Broadcast program scheduling is extraordinarily inconvenient for teachers and schools. Institutional arrangements for teacher security have not been developed. Teacher introduction to and training in the new devices and materials are primitive or not conveniently available. Investment and current costs are high and, with rapidly changing technology, can be wasted in a premature or erroneous decision.

There is no real paradox in the facts of an innovation of great potential and yet small utilization. As the instructional television

innovation is revolutionary, immature, costly, and not well understood (all of these things it is) and as the economic and societal sector upon which it impinges is mammoth, complex, traditional, and bureaucratized (which it is), then we should expect that the rate of development, adoption and diffusion of the innovation may take years and even decades. [See, for example, A.P. Usher, History of Mechanical Invention and S. Gilfillan, Invention of the Ship and Sociology of Invention].

Research Strategy

From this vantage point on we are led to strategy and design for analyzing and projecting the development of television instruction. We shall visualize stages and sequence in development. At each point in time, adoption and diffusion will depend upon: (a) the particular technological and economic characteristics of the television packages actually available, and (b) receptivity by individual teachers and the educational establishment at that time. There is need for flexibility, creative use, and learning in how to use the instructional TV. Further development of the innovation will in some cases depend upon successful results in prior stages of use.

The following is a summary map of the stages, sequence, and equipment packages which are discussed in detail in the subsequent pages. As noted earlier, we give only a few comments on satellite broadcasts and special areas. These are to be discussed in detail in subsequent papers.

Stage I

Approximately 1972-1976

Purpose: Experimentation and learning by classroom teachers.

Equipment: Package A. In each school 1 mobile TV set and 1 mobile video tape recorder/player (VTR) per 5 rooms; tape library; other items.

Stage II

Approximately 1974 onward. Depends on successful Stage I.

In substantial degree, full scale use of television instruction in individual schools, averaging 20 percent of classroom time. Continued development of program material and incorporation in formal classroom and individualized instruction.

Equipment Systems: 2 Alternatives

--Package A expanded to provide a TV receiver and VTR in each room, a large school tape library and certain other items.

--Or Package B plus Package C. Package B is a school wire (closed circuit) network to a TV set in each room. Package C is an active school head-end facility equipped with VTR's, tape library, and other items, which sends multiple programs on the school wire network to rooms, on request or according to schedule.

Stage III

Approximately 1976 onward. This stage might occur without Stage II, but its entrance depends on successful Stage I. Full scale use of television instruction, up to 20 percent

of class time as in Stage II. But programs are provided by the city school district from a centralized head-end facility to all schools.

Equipment: All alternatives require Package B, the school wire network to a TV set in each room. There are 3 alternatives for feeding programs to the school wire network and TV sets:

--Package D: a 4-channel ITFS broadcast system with centralized school district origination of programs, plus, at each school, an active head-end facility (like Package C, but of reduced size and activity) to record programs and provide delayed play as needed by schedules.

--Package E: 4-instructional channels on a city CATV system, with centralized school district origination of programs and active school head-ends, as immediately above.

--Package F: a <u>40</u>-channel school cable system connecting all schools and school district headquarters. The district head-end provides all programs. There are <u>not</u> active school head-ends, since the numerous program repetitions accommodate diverse school schedules without recording and delayed play.

<u>Stage IV</u>

Approximately 1977 onward. Builds upon previous stages. A substantial degree of satellite relay of instructional broadcasts to the head-ends of city school districts or of schools. These programs supplant some or all of the cities'

program origination activity of Stage III or the school origination of Stage II.

Equipment: Package G is a multichannel satellite system which relays to city head-ends. From there the signal travels to schools on a city cable network and to rooms on each school's cable network. Thus Package G substitutes for the city systems of Stage III. Package H is a multi-channel satellite which relays directly to school head-ends. The signals are carried to rooms on each school's cable network. Thus Package G substitutes for the individual school systems of Stage II.

3. Stage I, Experimentation and Learning by Teachers

The Initial Condition

We have said that a crucial question is the role and attitudes of teachers and of the school establishment, that they will continue to control education and that their preferences will greatly condition what can and will happen. One corollary is that class schedules will continue to be non-uniform among schools in a city, and even more so over larger areas. Another corollary, as previously noted, is that electronic programs will be used only if individual teachers: know what they are; believe they are useful; have the necessary hardware and software; know how to use them; can incorporate them into their notions of good education; can experiment, learn, and revise; and believe that the innovations promote (or at least do not threaten) teacher performance, security, and status.

A period of at least several years of discretionary experimentation and trial by individual teachers is necessary before the majority of teachers schools would learn how to use electronic programs. Only then would they feed back "demand" to program creators to provide large numbers of programs for substantial use in schools. Such "demand," of course, would be subject to school administrators' and boards' views on propriety, costs, and total budgets. Let us assume that electronic programs are potentially a great innovation for educational performance, i.e., for quality and efficiency. Then the question is how to bring teachers and the school establishment to an appropriate state of knowledge, cognizance, preparation and attitude, subject, of course to the cost

constraints which operate in most school districts.

At this time and for the next few years--Stage I of the television innovation--the innovation package most needed and needed most urgently is not that which educates students but rather that which educates teachers and supervisors.

Package A

We suggest that the preferred innovation package in Stage I is not the ETV stations or ITFS, which presently are receiving the major attention. Rather, it is the provision of mobile video recorder/players and associated TV sets, tapes and cameras, etc. in each school. The purpose would be to permit teachers to play and experiment with the new toy--educational television programs subject to teacher discretion in schedule, timing, handling, and methods of use.

Costs

Visualize a city-school district of 150,000 students as conceived by Michael Sovereign [Cost Studies of Educational Media Systems, 3 volumes. General Learning Corporation, 1968. ERIC Document Reproduction Service.] It has 136 elementary schools of 600 students and 46 secondary schools of 1400 students. Provide for each school and the school district headquarters the following research-development-learning package, which we'll name "package A."

Table I: Package A

	Elementary (20 rooms)		Secondary (50 rooms)		School District Overall
	No.	Cost	No.	Cost	
TV sets, B and W, @ $150	4	$ 600	10	$1,500	
Video players-recorders @ $700	4	2,800	10	7,000	
Mobile carts for above @ 300	4	1,200	10	3,000	
Program tape library, 20 minutes ea. @ $13	250	3,250	350	4,550	
Tape storage cabinets @ $300	3	900	4	1,200	
Portable video camera @ $400	1	400	2	800	
Totals		$9,150		$18,050	
Per Student		$15.25		$12.90	$14.47
Annual cost for maintenance, interest, depreciation, etc.: 1/3 of initial cost		$3,050		$6,017	
Annual cost per student		$5.09		$4.30	$4.83
School district headquarters		.15		.15	.15
Totals		$5.24		$4.45	$4.98

(Source: Appendix)

At the city-school district level package A provides a small black and white video studio (at $3,000), a film chain unit for converting films and slides to video cassette tape ($10,000), a couple of high speed video tape duplicators, and a staff member (at $8,000 per year). In annual equivalents, such school district costs add only about 15 cents per student per year.

Thus, the total cost in the aggregate of elementary and secondary schools and district spread over the 150,000 students would be roughly $5 per student per year. This compares with the average U.S. school budget of about $800 per student, of which roughly $500 goes for teachers

and $300 for other expenses. The $5 cost for the introduction of the above television experimentation would be about 2/3 of 1 percent of the annual school budget.*

Performance

What would we get for the expenditure of about $5 per student per year for package A? We would put conveniently in the teachers' hands television instruction cassettes, video players and TV sets, for their review and experimental use. Also, there would be cameras for experimental efforts in taping their own, their colleagues' and students' presentations. There would be opportunity for them to study the devices and programs, outside of school hours as well as within. Still further, there would be a sufficient number of television sets and recorders that selected ETV and other broadcast programs could be picked up and shown to classes, live or from recordings. The teachers' own schedules and individual preferences could be accommodated. And so on.

Of course, some teachers would not even look at the tape programs nor show them to students. But most of the teachers would.** They would

*This cost derives primarily from a total capital cost of about $15 per student. It excludes costs of producing the programs which are on the tapes, based on any one of 4 assumptions: (1) The costs have been spread over so many users in the Nation as to be insignificant. For example, if an average of $4,000 per tape was spent to produce 4,000 20-minute tape programs per year, this would be only 30 cents per student per year in the Nation. (2) Tape or film material in the public domain is used. (3) Program cost has been subsidized by the Federal Government. (4) A combination of these. In the meantime, note that even if we add 30 cents per student per year for program costs, this raises the per student figure to only about $5.30 per year, which is still less than 2/3 of 1 percent of the annual school budget.

**See, for example, J.R. DuMolin, op.cit., p. 26, and the J.W. Mohrman and W.E. Wise table and reference reproduced there.

learn something about the new medium. They would learn something about how to use it and not use it in their classes. Teachers, fellow teachers, students, and innovation--all would be interacting. From this, gradually would develop desire and effort to make use of the innovation in the education of students, beyond mere experimentation with a new device in efforts to learn its possible uses and preferred characteristics. The maturation from experimental device to effective teaching instrument would take time, from a couple of years to half a dozen, perhaps, depending on types of schools, budgets, etc.

Breakthrough in Video Recorders/Players

The foregoing seems an obvious initial step, given our decentralized and uncoordinated individual school systems. Why has not such a scheme been widely proposed and adopted? The reason is that it could not have been before now. The breakthrough of cheap video recorders/players and cheap video cartridges is only just now occurring--indeed will not happen till next year or the year after. If recorders/players and tapes still were to cost what they did when Sovereign or Carter-Walker [The Schools and the Challenge of Innovation, Committee for Economic Development, 1969] prepared their major studies in the latter 1960's, then the costs would be ten-or twenty-fold higher. A city would not happily allocate so large a fraction of a community's school budget--by far the major expenditure of our cities--to provide a large array of devices for teachers to play and experiment with in Stage I of the TV innovation. Further, if such moderate-scale experimentation were, say, 10 percent of the school budget, then would not the cost prospect of large scale use be prohibitive?

On the other hand, it is reasonable to believe that the city and school system could authorize teacher and school system experimentation and learning for an annual cost of, say $5 per student per year if the innovation has great promise for improving quality or reducing cost of instruction. Further, the prospect for significant expansion, as some of the experiments gradually became successful would not be frightening. Assume, for example, that the experimental Package A system because of demonstrated success were expanded 5-fold in Stage II of the TV innovation, to a video player/recorder and TV set in each room and appropriate expansion in the other elements of the package plus staff help. Then (as shown in the next section which describes Stage II), the annual cost would rise to about $29 per student per year, approximately 4 percent of the total school budget. This would be for an innovation which had already demonstrated high productivity in improving quality or saving other costs, or else the expansion in Stage II would not be approved by the School Board.

Observations

Several further comments need to be made before leaving Stage I. First, we do believe that our focus on package A--teacher experimentation and learning with video players and TV sets--is the proper first priority for Stage I of the school TV innovation, and that ETV and ITFS are not. Package A makes television a working and developing tool in the hands of teachers; teachers learn about television instruction from it and acquire ability to use it; it accommodates much better to teacher and school schedule needs; and it is much more ample and flexible.

Second, broadcasts by ETV stations can nevertheless be a very useful supplement to package A during the Stage I experimental period

of the TV innovation. The ETV stations already exist. Their VHF or UHF channels if used at all during school hours are primarily devoted to instructional programs and can be received by any standard TV set. The large number of schools TV sets provided in the experimental video player/recorder Package A, above (approximately 300,000 to 400,000 in the Nation), would greatly enhance school ability to receive ETV programs. Further the school video recorders could tape the ETV broadcast programs which arrive at inconvenient times and use them at convenient times. Some of the ETV broadcast programs will be very good, and in these cases we can expect teachers to try to incorporate them into their learning and teaching efforts, both as live programs and after taping. In summary, single channel ETV which is now a rather inadequate form of the TV innovation in this country would be a much more valuable service if schools had more TV sets and could tape programs for multiple use and reuse at suitable times.

Third, there are desirable activities additional to package A which should occur in Stage I, which we have not considered. One of these is the introduction of enlarged and improved courses on the use of TV instruction for students in the teacher colleges and for teachers in their summer and post-graduate study programs. This is obviously very important in view of Stage I objectives. And there are surely other needed activities.

Fourth, we are aware of at least two qualifications on the video player package A proposal we have put forward as the major element in Stage I. It is sharply tuned to what we think is the institutional and political economy reality: decentralized school systems; considerable

teacher autonomy; individual school schedules; the need for learning, experimentation, and flexibility with the TV innovation; costs; etc. As a corollary, our proposal may be less suited to a set of different social parameters: a single national school system, greater concentration of authority, stronger central planning and direction, etc. The second qualification is of a different nature. Ours is a preliminary study by economists, involving electronics, education, etc.--fields which are literally exploding with new information and developments. We have not considered all possible alternatives or additions for desirable packages in Stage I. Nor have we considered program material production and legal issues. Our study has been limited in time and available resources.

4. Stage II, General Use of Television Instruction in Individual Schools

Assume now that after a few years the teachers and school establishment have learned to employ the TV instruction innovation. It has been found to be very effective in improving quality of education and economy, and school systems desire to employ it. The new "product" is large-scale improvement in education.

Alternatives

One possibility is simply scale expansion of package A, as was mentioned above, to a five-fold level, plus some staff help. This would be about $29 per year per student.

Another possibiliy, however, is to create a more structured situation in the school. We can create a closed-circuit wire network in the school with TV sets in each room; in addition there will be some video recorders and sets for individual's use. These we'll call package B. The wire network will be served by an active head-end facility. The head-end, which we'll term package C, would have a battery of video recorders/players. It would also have facilities for receiving cable or broadcast signals from outside and recording them, or passing them directly into the school wire network to one or more classrooms; would centralize the tape library; and would employ a person to conduct the head-end operations, including tape playing as requested by teachers for class use. Packages B and C together total about $33 per student per year in the school district.

Thus we have as alternatives: (i) Expanded package A in which video players and the playing of cassettes is decentralized to the

individual rooms, or (ii) package B + C, in which the video playing occur in a school head-end on request of the individual teachers, and the programs are sent to the individual rooms by wire. As a first approximation, each of the systems seems to cost the school district roughly $30 to $40 per year per student:

Table 2: Costs of Expanded Package A and Packages B + C

	Expanded Package A	Packages B + C
Elementary school	$32.70	$42.85
Secondary school	27.60	23.64
Average in school district, weighting elementary twice secondary	$29.28	$33.22

Equipment and Cost Estimates of Packages B + C.

A list of items and prices entering into packages B and C is shown in the long table on the next page. The package C component is by far more expensive than B.* It is almost 4 times as large as package B in the elementary schools and almost twice as large in the secondary school. The reason is that the active head-end has as one component an $8,000 per year staff member running it. In an elementary school of 600 students, he costs $13.33 per student each year. In a high school of 1400 students he costs $5.70 per student each year.

Nevertheless as shown above, package B + C is only moderately higher in total cost than expanded package A, because of economies in video players, tapes and related equipment. And, in fact, package B + C is lower than expanded package A in the secondary schools, because of economies of scale. On these data small schools will find expanded package A cheaper, large schools will find B + C cheaper. Since each school is an separate unit in this form of instructional TV, some schools within the same district might go for the expanded A package, others to the B + C. In such selection, small schools would cost about $33 per student per year and large ones about $24. And, of course, school districts composed entirely of small schools or entirely of large ones could similarly choose, respectively, the cheaper TV systems.

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*The salient annual figures are:

	Elementary	Secondary	School District
Package B wire network, TV sets, and individual use items	$ 8.95	$ 8.12	$ 8.58
Package C active head-end	33.90	15.52	24.64
Total	$42.85	$23.64	$33.22

(Source: Appendix)

Table 3

Packages B and C

	Elementary school (20 rooms)		High school (50 rooms)	
	No.	Cost	No.	Cost
Package B (school network and other):				
·Wire network items:				
School cable network @ $40/room	20	$ 800	50	$ 2,000
School cable wideband amplifier @ $300	1	300	2	600
Cable TV sets, B/W @ $250	20	5,000	50	12,500
Subtotal wire network items		$ 6,100		$15,100
·Individual use items:				
Video recorders/players @ $700	2	1,400	4	2,800
TV sets @ $150	2	300	4	600
Deluxe carts @ $300	2	600	4	1,200
Special tape library @ $13	200	2,600	200	2,600
Camera and blank tapes @ $400	1	400	2	800
Viewing booths @ $550	2	1,100	8	4,400
Storage cabinets @ $300	2	600	2	600
Subtotal individual use items		$ 7,000		$13,000
Subtotal Package B items		$13,100		$28,100
·Administration of Package B, per year		$ 1,000		$ 2,000
Package C (active school head-end):				
Video recorder/player/monitor @ $1000	4	$ 4,000	6	$ 6,000
Tape library @ $13	1,800	23,400	1,800	23,400
Storage cabinets @ $300	18	5,400	18	5,400
Antenna @ $400	1	400	1	400
Subtotal Package C items		33,200		35,200
Administration, per year		$ 1,000		$ 2,000
Head-end person, per year		$ 8,000		$ 8,000
Packages B and C recapitulations and calculations per student				
Package B:				
wire network items		$ 6,100		$15,100
individual use items		7,000		13,000
total items		$13,000		$28,100
annual equivalent @ 1/3		$ 4,370		$ 9,370
administration, per year		1,000		2,000
total, per year		$ 5,370		$11,370
total, per year per student		$ 8.95		$ 8.12

Table 3, continued

	Cost	Cost
Package C:		
total items	$33,200	$35,200
annual equivalent @ 1/3	11,070	11,730
administration and salaries	9,000	10,000
total per year	$20,070	$21,730
total per student	$ 33.45	$ 15.52
Packages B and C:		
total per year	$25,440	$33,100
total per year per student	$ 42.40	$ 23.64
total per year per student in school district	$33.22	

(Source: Appendix)

In both systems, the quality and quantity of TV instruction could grow as program material accumulated and teaching techniques and equipment were improved. Doubling the volume of TV instruction from 20 percent to 40 percent of class time would not, of course, double the cost.

Finally, we compare the costs with the school budget. The average of $36 per student per year of packages B + C in Stage II would be roughly 4 percent of the average school budget of about $900 per student per year in 1975. The $29 of expanded package A would be about 3-1/4 percent.

Performance of the Two Systems

The systems provide about 20 percent of the class time instruction. Is this performance worth, say, $36 per student per year? What would we get for the outlay?

Both systems have very good capability and flexibility for providing individualized TV instruction for both fast and slow learners,

after hours and during library time. Conceivably also there could be some saving of teacher time and energy, and some of this might go to instruction and attention to individual students.

If the program material were good, if the teachers know how to use it, and if the learning context were favorable, then the 20 percent of class time allocated to TV instruction could greatly enrich the students' learning. This quality improvement above, if it occurred, could be worth much more than the 4 percent of the budget it costs. We are already spending more than $150 per child per year for each 20 percent of his hours. If we could upgrade quality of instruction and reduce dead time and boredom, this could surely be worth $33.

It is possible that society would not choose to allocate $33 per year per child, additional to what they would have spent anyway. If so, it is still possible that we can get better total performance in the schools by substituting TV programs in part of the day's fare for teacher time. For example, the TV instruction might permit increasing the class size per teacher by 8 percent, from the present average of (say) 25 students per teacher to 27. Such increase in class size would reduce teacher cost per student per year from about $500 per student per year to $460. The $40 saving would be approximately the cost of the TV instruction program.

Finally, a comment on the respective merits of the two systems. We suspect the package B + C is in general superior to expanded package A, and that this would more than offset the slightly higher cost of the former in the elementary school:

- Package B + C can receive cable inputs. It could also be adapted to receive ITFS and satellite broadcast signals.

- The quality of VHF and UHF broadcast signal service to classrooms is superior in package B + C, due to better antenna and amplifier.

- Package B has library TV booths and video recorder/players for teachers and students who desire this, additional to the head-ends.

- Package B + C can feed the same tape programs to several or all rooms simultaneously.

- The non-duplicated tape library in package B + C is about 1-1/2 times as large as in package A.

- Package B + C provides an inter-room communication service for school announcements and sound radio signals generally.

5. Stage III, City-School District Instructional Network

We continue to inquire into alternative television instruction systems, following the several years of successful experimentation, research and development, and learning in Stage I. The Stage II alternatives just considered were individual school systems, either (i) an expanded package A (in which each room had its own video player/recorder in addition to its TV set) or (ii) package B + C (in which the room TV sets were served by a school wire network and a school head-end facility with video recorders). The costs for these two packages were quite similar, at about 4 per cent or a bit less of the average school budget in 1975.

There is, however, a major alternative to the package B + C or the expanded package A systems in which each school operates its own television instruction system quite independently. The alternative is to originate programs from a city head-end facility and convey them on a city-wide television network to the schools. There they would be delivered to the individual rooms on the schools' wire networks.

For this alternative there are three possible packages which could be used:

Package D: A four channel ITFS (instructional television fixed service) city network served with programs from a central city head-end. This is a television broadcast network to schools on 2,500 MHz, as presently sponsored by the F.C.C. Schools would need special reception equipment; a head-end video recorder/player system to record programs and play them when needed according to the indivudal school's schedule; and a school

closed circuit wire system to route programs to the individual TV sets in classrooms, either when received or later from the tapes which the school recorded.

Package E: Four channels on the city cable network which would be exclusively devoted to school service. Programs originate at a city head-end facility. As in Package C, just described, the school would have a head-end video recorder/player system to record programs for play when needed, and a school closed circuit wire system to route programs to classrooms, either when received or later from the school's tape recording.

Package F: A forty channel cable network exclusively devoted to school instructional service. This city network as well as the closed circuit networks in schools are wire systems. Programs originate at city head-end facility and are piped to all school rooms. Half to two-thirds of the large number of channels are devoted to numerous program repetitions on a fixed schedule. The remainder of the channels are for further program repetitions or showings in response to requests. In this package, the school does no video recording or playing at its head-end, since the 40-channel offerings from the city head-end provide sufficient multiple repetitions to satisfy the diverse schedules of the schools.

We may summarize these 3 packages in Table 4, on the next page.

Table 4: Comparison of City School Networks

	Package D	Package E	Package F
Number of Channels	4	4	40
City Head-End Broadcasts	Yes	Yes	Yes
Signal Conveyance to schools	2,500 MHZ over the air	CATV system of which 4 channels for schools	Dedicated district coaxial cable system
Special School Reception Equipment	Special Antennas and down converters	None	None
School Head-End	Active, with equipment to record, hold and play 3 weeks of programs.	Active, with equipment to record, hold and play 3 weeks of programs.	None
Intra-School Network	Cable	Cable	Cable

A few words may be useful to explain why the packages are so constructed. The package D ITFS system is limited to 4 channels because of F.C.C. decree and the limits of available frequencies. Four channels, however, would permit only about 2 offerings of each program (See Appendix). Since this is insufficient to meet the schedule diversities of the schools over hours of the day, days of the week, and among weeks, an active head-end at the school is necessary to record the program for delayed play. It would be like package C, but reduced in size.

We constructed package E to match these ITFS capabilities, in the cases where the city might have a commercial or municipal CATV system. For an annual charge the CATV dedicates 4 channels to school service. The fee assumed is one-fifth of the annual cost if the school system were to construct and operate its own city-school cable network of 40

40 channels.* As in the ITFS package, an active-head-end facility is necessary at each school to record and play back later.

Package F is our own conception. Its 40 channels permit numerous repetitions from the city head-end. Also there is service by the city head-end upon request. [See Singh and Morgan, op.cit. p. 58 and D.S. Abbey, "Information Retrieval Television", Audiovisual Instruction, Feb. 1971, pp. 44-45.] With this number of channels and volume of service, there is no need for active school head-end facilities.

Costs

Table 5 on page 30 lists the equipment and other costs of the alternative systems of stage III. All of these provide a city-wide network and program origination from a centralized city head-end facility.

The city is assumed, as before following M. Sovereign, to have 136 elementary schools of 600 students and 46 secondary schools of 1400 students. Unlike Sovereign's city, however, ours has a radius of 10 miles and area of 314 square miles. This is more than twice the radius and 4 times the area of the city assumed by Mr. Sovereign. Since we have adopted the school data and population of Sovereign's city, this means that we have a population density less than one-fourth of his.

The reason we decided not to adopt Sovereign's city of 70 square miles is that it was patterned after Washington, D. C. and was not typical of U. S. cities in population density. [See Table in the Appendix which shows population densities of 130 cities in the U. S.

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*In New York City and some other cities, the CATV franchise requires that a number of channels be available to the school system, without charge. See also J. Singh and R. P. Morgan, Educational Electronic Information Dissemination and Broadcast Services, Washington University, August 1971, pp. 58,60.

with populations in excess of 100,000 in 1970. Sovereign's density of 11,500 per square mile is near the top of the list.]

Our enlargement of the area of our hypothetical city and consequent reduction of population density puts us near the bottom of the list. In the table, 121 of the cities have population densities higher than the 2,500 per square mile of our hypothetical city and only 9 have population densities smaller.

Table 5: Comparison of Stage III City Systems

	Package D 4 Channel ITFS	Package E 4 Channel Cable	Package F 40 Channel Cable
		($ per student per year)	
City network, transmission reception	$ .92	$ .59	$ 2.86
City head-end origination	.50	.50	2.23
School head-end for recording from 4 channel systems and providing up to 3 weeks of delayed play in schools	8.66	8.64	0
Subtotal	$10.08	$ 9.73	$ 5.09
Package B: in-school wire networks, TV sets, etc. (see p. 20 above)	8.68	8.68	8.68
Total--city origination systems	$18.76	$18.41	$ 13.77

(Source: Appendix)

We have made a major, exciting discovery. The school district can own and operate a 40 channel cable system into the schools, can provide many repetitions of programs sufficient for flexible schedules and 20 percent of class time, and can provide all the necessary school equipment for only about $14 per student per year. This is only less than half the cost of the stage II alternatives. It is only about 1-1/2 percent of the annual school budget.

The school district can acquire its own 40 channel cable network connecting all its schools and a central head-end facility for very small cost--only about $2.86 per student per year. Even though spread out and of low density, our city of 10 mile radius requires only about 255

miles of cable. (If the city were as dense as the Sovereign model, it would require only about 100 miles of cable.) As compared with stage II systems, this wired city can achieve great economies of scale by running a single, large head-end facility. This pumps out on (say) 2/3 of its 40 channels many repetitions of programs to meet schedule variations over the day, the week, and weeks. It also responds to special requests on a dozen or so of its channels. Active school head-ends are unnecessary with this volume and flexibility of service. The very large city head-end of package F costs only a bit more than $2 per student per year. By comparison, the package C school head-ends in stage II cost about $25 per student per year, because of the dis-economies of small scale. Similarly, the 40 channel head-end of package F is much cheaper than the aggregate of city and school head-ends of the 4 channel city systems, package D or E. These latter cost about $9 per student per year. Their difficulty is diseconomy of small scale in operating active school head-ends as compared with the efficiency of the single large-scale city head-end facility.

Another noteworthy observation may be made concerning the stage III systems in Table 5. The ITFS conception in package D, is cost-wise no better than renting 4 channels on a CATV system at 1/5 of the cost of an entire cable system. By the time one pays for special ITFS transmission and reception equipment, the cost is as high as the cost of 4 channels on the cable. This is quite apart from the better picture quality of the cable relay.

The foregoing is true with our assumptions concerning areas which are favorable to ITFS. For cities with

population densities higher than our 2,500 per square mile, or in situations where the ITFS omni-directional signal will not suitably cover a 10 mile radius, ITFS costs relative to cable would be even less satisfactory.

Finally, we may note the sequence relation of stage III to stage II. If stage II has the expanded Package A, then it does not easily "mature" into stage III. For stage III to enter, it would become necessary to wire up the schools. If in stage II the system had chosen Package B and C, then it could more easily "grow" into stage III. The school wire system would exist and teachers would have become accustomed to service from outside, rather than running individual video recorder/players themselves.

Performance

In general the several alternative packages of stage III perform about equally in terms of program offerings. On the 4 channel systems the city head-end broadcasts provide about two repetitions of each program; and the school head-ends record and hold programs for 3 weeks, for playback on request. In service to the teacher this is about equivalent to package F. Package F provides an average of a dozen or so repetitions of each program on a prestated schedule, which presumably was formed by surveying teacher schedules in the first instance; and it also provides special offerings on perhaps a dozen channels on telephone requests from the teachers. In addition, a teacher can always tape a program for his students' later or repeated use on one of the mobile

recorders which is in package B (see p. 18). So in programs offered and flexibility the systems seem equivalent.

In signal quality, however, the ITFS is sometimes inferior in the sense that over-the-air reception is subject to atmospheric interference and obstructions while cable is not.

It is in cost that clear superiorities appear for stage III over stage II and for package F over all other arrangements. Stage III systems are all cheaper than stage II, and the dedicated 40 channel cable system (package F) is in cost-terms superior to the 4 channel systems. The comparative figures are as follows:

Table 6: Comparative Costs of All Systems

	$ per student per year
Package F: 40 channel cable system (includes Package B, school wire network)	$13.77*
Package E: 4 channel cable (includes Package B)	18.41*
Package D: 4 channel ITFS (includes Package B)	18.76
Package A Expanded	31.07
Package B + C	33.22

What might be the trends of these 1975 costs over time, apart from inflation? Wage and salary rates tend to rise at 3 or 4 percent per year, while capital charges tend to be constant or decline.

* See Footnote, Next Page.

The cost advantage of Package F, which is the most capital intensive system might increase over the years.

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*We have had criticism of our use of $5,000 per mile for cable, primarily on the ground that the cost would be greater if most cities required underground construction. On this assumption we think the criticism would be valid for many cities. Depending upon cable costs per mile, the above figures vary as follows:

	Cost per student per year	
Cost per mile	Package E	Package F
$5,000	$18.41	$13.77
$7,500	18.71	15.20
$10,000	19.00	16.63

The conclusions already recited on cost superiority of the 40 channel cable system remain unchanged.

6. Stage IV, Satellite Relay and National Broadcasting

This subject matter is undergoing research and will be reported in a later paper. Here we merely sketch out our present thoughts in a speculative way to give preliminary views.

Assumptions

We now assume that we are in the year 1976 or thereabout. Each school building is equipped with package B--a wire network to TV sets in each room plus some individual use equipment, as described earlier on p. 18. There has developed a substantial volume of TV program sending from school headends and/or city headends (stages II and III).

Satellites and national broadcasting now are assumed to offer an equal-service, alternative system for sending and relaying programs. The elements in this assumption are as follows:

(i) The quality of pictures and the certainty of scheduled service are equal to the systems already discussed.

(ii) Despite national broadcasting from a central source, neither the Federal Government nor any other central authority dictates program content and diversity. Programs are as diverse as in stages II and III. The system is fully acceptable to the State and local educational establishments and teachers for 20 percent of class time.

(ii) As in stages II and III, teachers and schools have diverse schedules and preferences, and will accept programs only as they individually choose. The satellite system will have to broadcast many repetitions on 20 to 40 channels. Or else there will have to be recording, storage, and playback at city or school head ends; (see, e.g., packages D and E, above, where school head ends recorded, and stored 3 weeks of programs).

(iii) Our concern is long-run average costs, and so we will ignore the possibility of obsolescense of sunk costs in existing city or school head ends or city networks.

We now examine two satellite packages.

Package G: Satellites service to cities

In Package G, a national ground station with active head end facilities transmits 20 to 40 programs simultaneously to one or more satellites. The satellite(s) relay the signals to city head ends (antennas, down converters, modulators, amplifiers, etc.). The city head ends pass the programs on to schools via city cable networks. The schools pass them on the schoolroom network to all individual rooms and TV sets, for individual selection by the teacher.

We may compare this new package G with package F, the 40-channel cable system described above, for the Nation as a whole.

	Package F	Package G
Program origination facilities	*Many active city head ends	*One active national head end
Relays:		
To city head ends	*Parcel Post (tapes)	*Ground station transmitter
		*Satellites
		*Many city ground stations, antennas, etc.
To schools	City school cable network	City school cable network
In schools to rooms	Package B	Package B

The trade off is between the two items marked * in Package F, on the one hand, and the four items marked * in Package G, on the other. The other items are the same. Let us ignore several of the divergent items as being a relatively small cost when spread over the whole U.S. student body: *parcel post; *the one active national head end; *the one ground station transmitter.

Then the trade off is the underscored items: *package F active city head ends for *city ground stations plus *satellites. The number of active city head ends in F is the same as the number of city ground stations which receive the satellite signals and pass them into the cable network in G. Assume the number in the Nation is 300. Then the package F annual head end cost in the Nation is 300 x $334,000 each, a total of about $100 millions. If this is less than cost of 300 city ground stations plus the satellites, then package F is cost-wise better. On the other hand, if cost of city ground stations plus the satellites is less than $100 millions per year, then package G is cost-wise better.

No 20 to 40 channel satellites or ground station receivers have been designed, so we cannot compare estimated costs. What we can do is discover that the satellite system, Pack. G is conceivably promising. The $100,000,000 per year which could be saved from package F could buy a great deal of package G. The following are two illustrative combinations of ground station and satellite annual costs which would make package G competitive with package F:

	Annual Cost
Ground Stations, each at $100,000 per year	$ 30,000,000
Satellites	70,000,000
	$100,000,000
or	
Ground Stations, each at $50,000 per year	$ 15,000,000
Satellites	85,000,000
	$100,000,000

Eight-channel ground stations have been proposed in the literature at cost figures very much smaller than the $100,000 annual cost illustrated above. There has been speculation on satellites of up to 8 or 10 channels at cost figures lower than the annual costs illustrated above. In satellite technology one can usually trade between ground station and satellite cost: more power in the satellite saves ground station cost. And better ground stations save on satellite costs.

Given the assumptions previously stated, it is not impossible that a satellite system could be cost-wise an efficient alternative to the efficient Package F cable system previously described.

Package H: Satellites to Schools

In package H the signals are sent to and received by the individual schools, then conveyed on the school wire to classrooms. Package H is thus a competitor of the systems in stage II, in which the individual school was the unit which originated programs. Specifically package H may be compared with Package B + C.

	Package B + C	Package B + H
Program origination	*Thousands of active school head ends	*One national head end
Relays: To schools	*Parcel post (tapes)	*Ground station transmitter *Satellites *Thousands of school ground stations, antennas, etc.
In schools to rooms	Package B	Package B

As previously, we ignore the common item (Package B) and the relatively small items--parcel post, the one national head end, and the one ground station transmitter.

This leaves us with the trade-off of tens of thousands of school active head ends for tens of thousands of school antennas, receivers, etc. plus the satellites.

Assume 50,000 schools. The active school head end costs about $20,000 per year. Multiplying 50,000 x $20,000 = $1 billion per year. Can one create a satellite system to 50,000 schools for $1 billion or less per year?

Some illustrative figures are as follows:

	Annual Cost
50,000 School antennas, receivers, etc. at $10,000	$ 500 million
Satellites	500 million
	$1,000 million

or

	Annual Cost
50,000 School antennas, receivers at $16,000	$ 800 million
Satellites	200 million
	$1,000 million

The question which we cannot answer is whether 20 to 40 channel satellites and receiving stations could be built and operated for $1 billion per year or less. If so then the satellite could be cost-wise a competitor as against the somewhat expensive ($33 per year per student) package B + C.

Service to Special Areas

In all of our costing we have assumed cities of 150,000 students, 146 elementary schools, and 36 secondary schools, etc. What about other areas? Our thoughts are very preliminary.

In general, sparsely populated areas and/or areas with small schools could not be served as cheaply as our hypothetical city. The most efficient city system, package F ($13 per student per year) would suffer increasing costs from increasing cable distances; and ITFS ($18) is also a city-oriented system. An upper bound on cost, however, is placed by package A expanded ($29) or package B + C ($33). Their fundamental cost is per room or per school, and is not significantly affected by sparseness of settlements.

Take Alaska, for example. Assume 78,000 school children and class room sizes of about 30 students or a bit less. Package A expanded would cost about $29 per student per year, a total of about $3 millions per year. The video recorder/player breakthrough apparently is a promising innovation for sparsely populated areas. The new element which has not been generally appreciated in this context is the flexibility and small scale cost of VTR.

A major interest is whether satellites would have virtue for such areas, e.g., mountain regions and Alaska. Assume that the single, multi-channel satellite system could serve a number of sparsely populated areas--Alaska, some Indian reservations, Southwest desert, and Rocky Mountains, with a school population 10 times as large as Alaska. The alternative package A expanded costs would be 10 times as large--$30 millions. The question we are now researching is whether full satellite service, including ground reception and other factors, could be provided to these difficult service areas for $30,000,000 or less.

Beyond the question of a dedicated satellite ITV system for schools is that of use of multi-purpose satellites for instructional TV in

sparsely populated areas. If satellites are already flying in the sky and head ends are already operating and there is excess capacity then the marginal costs for these elements in providing ITV services to the sparsely populated area might be very low; the only significant marginal costs might be reception and distribution in the school.

At this time we have no answers on the cost effectiveness of satellites relative to other systems for instructional TV.

APPENDIX

This is now in final preparation and will be available shortly.